The Properties of Individual Aerosol Particles Sampled over North Slope of Alaska during ISDAC

Alla Zelenyuk, Dan Imre,
Peter Liu, Anne Marie Macdonald, and Richard Leaitch

Pacific Northwest
NATIONAL LABORATORY

SPLAT II

- Provides in *real-time* the size and internal composition of individual particles in 50 nm to 3 μm size range
- Measures refractory and non-refractory aerosol fractions in each particle
- Yields size distributions (d_{va}) and number concentrations
- Sampling rate: sizes up to 2000 p/sec, 20-50 of which are also chemically characterized
- High sensitivity to small particles: detects 40% of 100 nm particles
- High overall sensitivity: detects 1p/sec for an aerosol sample of 1p/cm^3 with d>100 nm

Pacific Northwest
NATIONAL LABORATORY

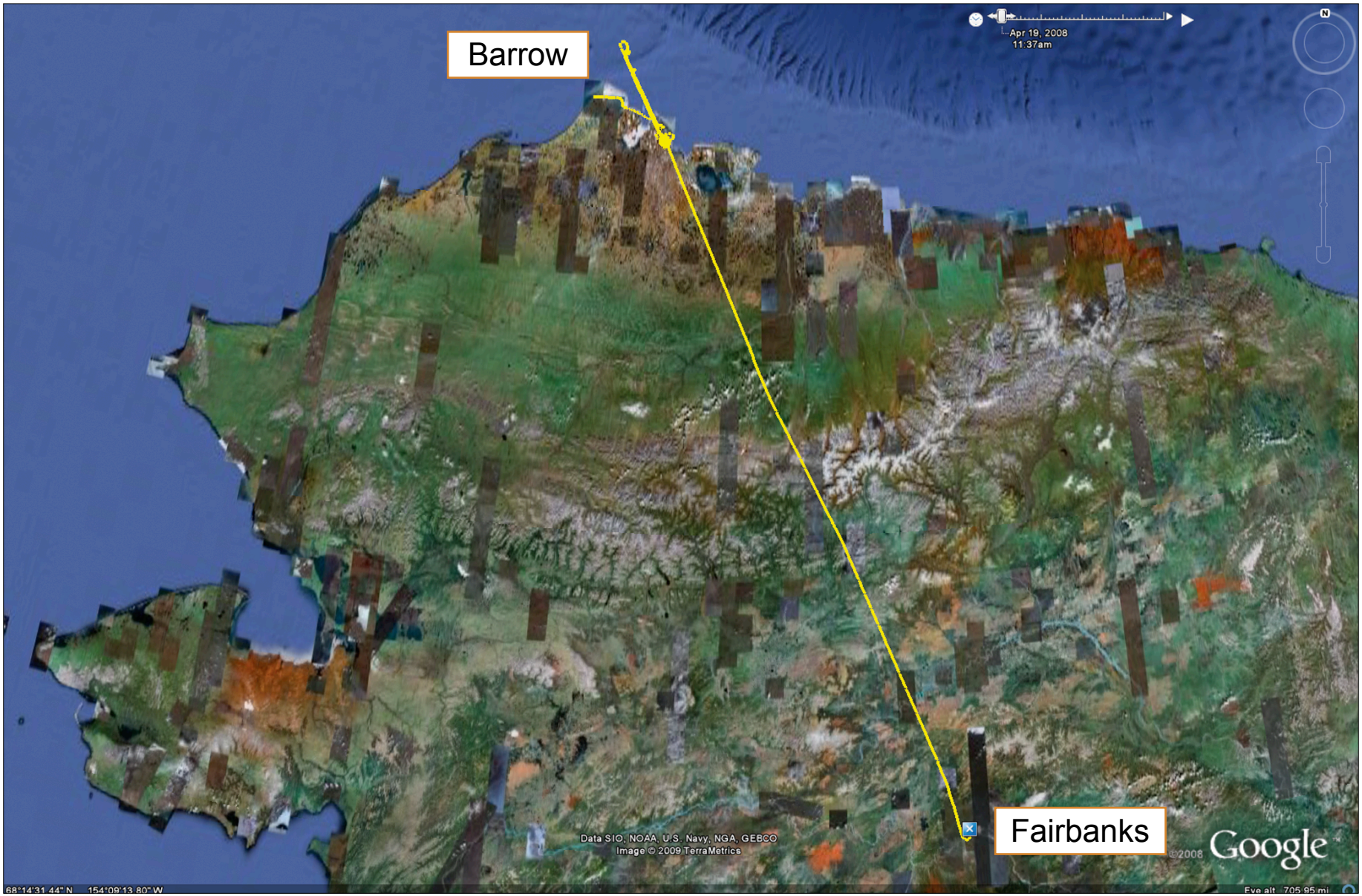
SPLAT II Data

- During ISDAC SPLAT II participated in all 27 flights that lasted slightly over 100 hrs.
- It measured the size of tens of millions particles and characterized the composition of over 3 million of them.
- SPLAT II was sampling particles alternately through the aerosol inlet, to characterize the composition and size of the overall aerosol population, and through the CVI inlet to characterize the composition and size of particles that served as CCN and IN.

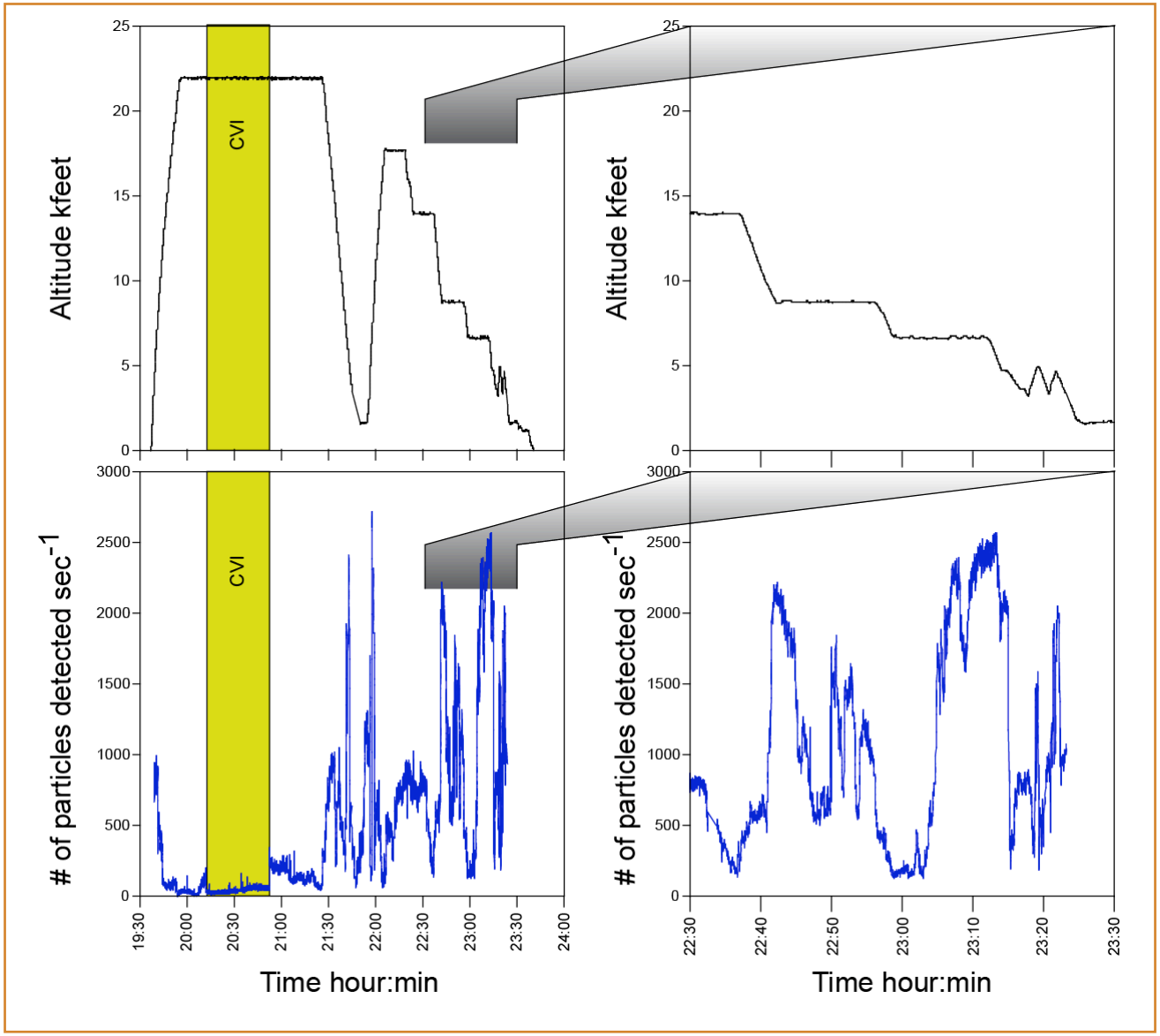
Examples: April 19, Flight 25 & 26

Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 25



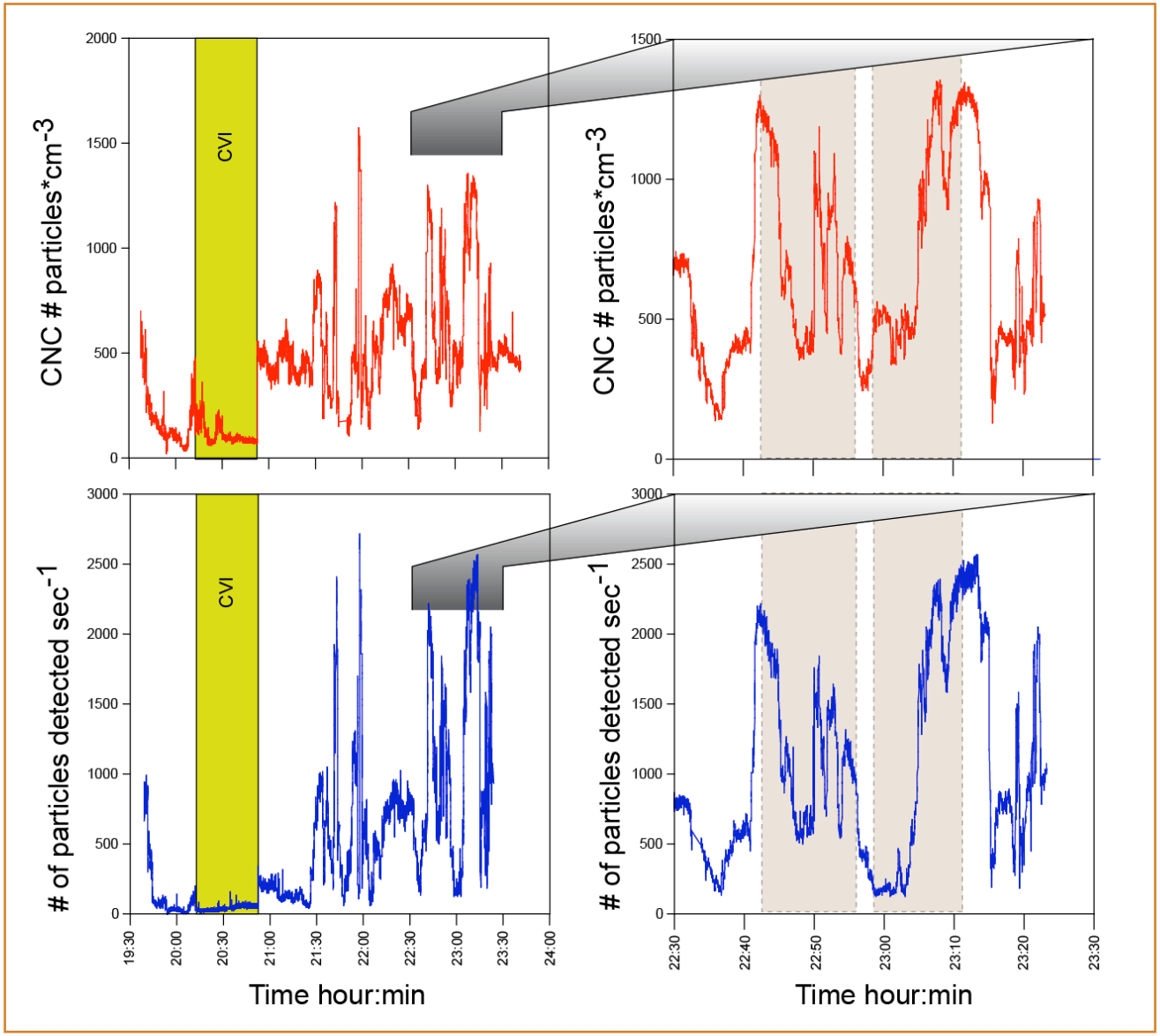
April 19th, Flight 25



Depending on particle loadings SPLAT detects between a few particles to thousands of particles per second.

Pacific Northwest
NATIONAL LABORATORY

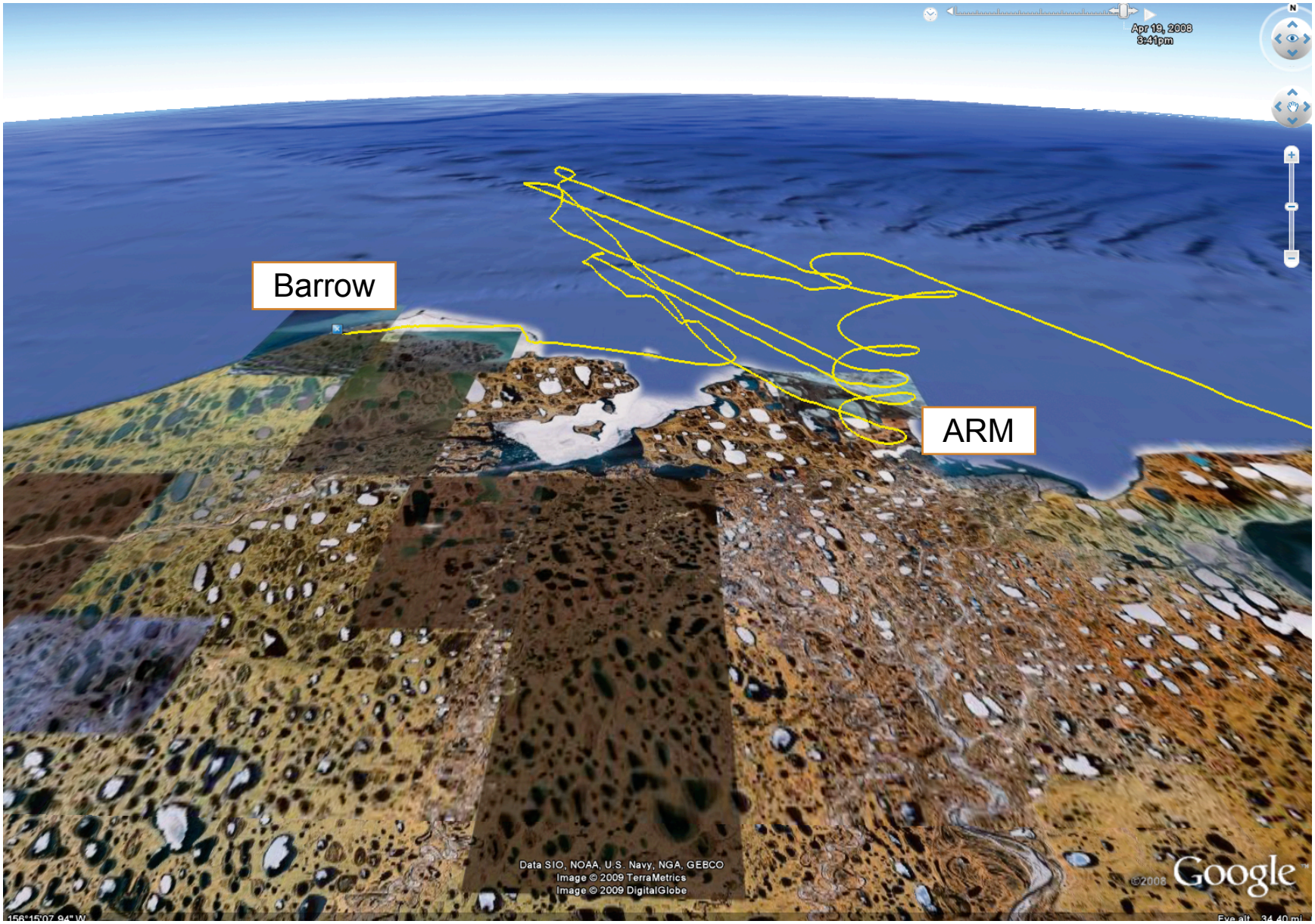
April 19th, Flight 25



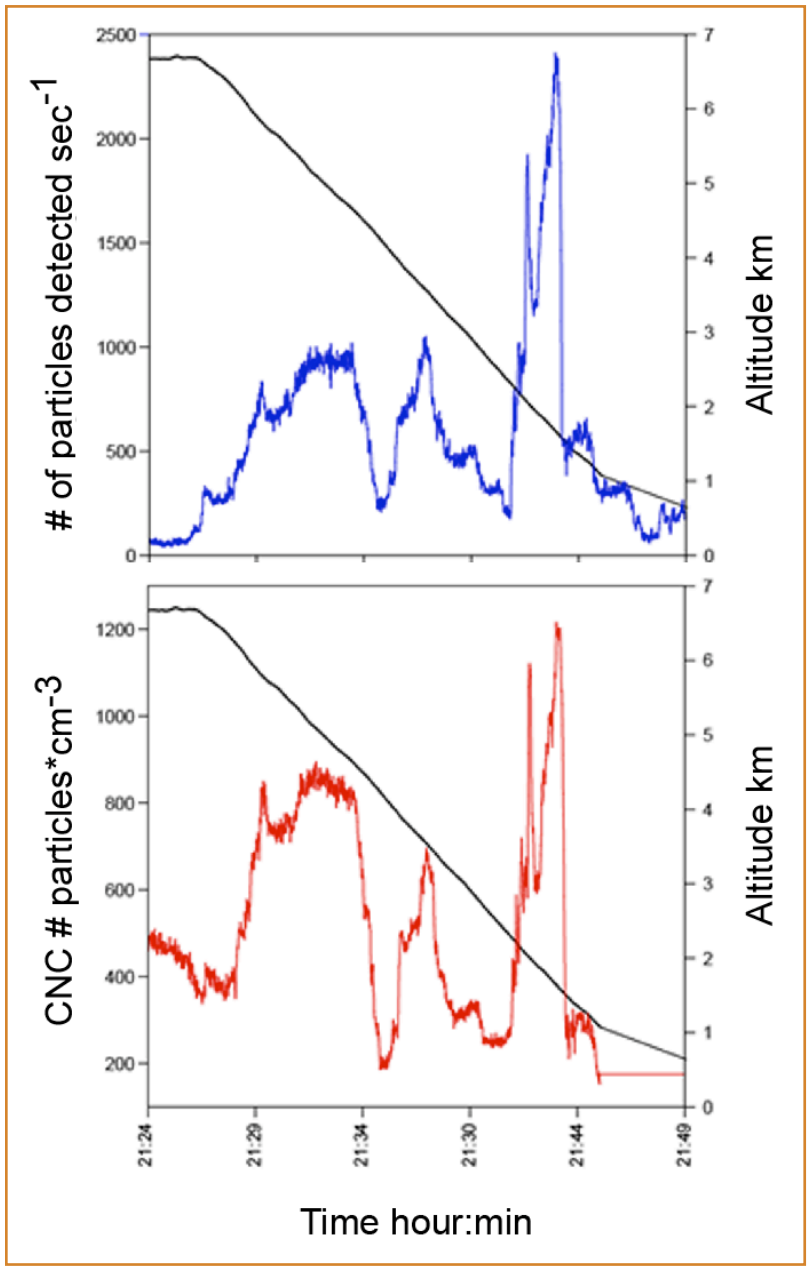
The number of particles detected by SPLAT follows the CNC counter closely. Moreover, we understand when and why the two differ.

Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 25 Vertical Profiling



April 19th, Flight 25 Vertical Profiling



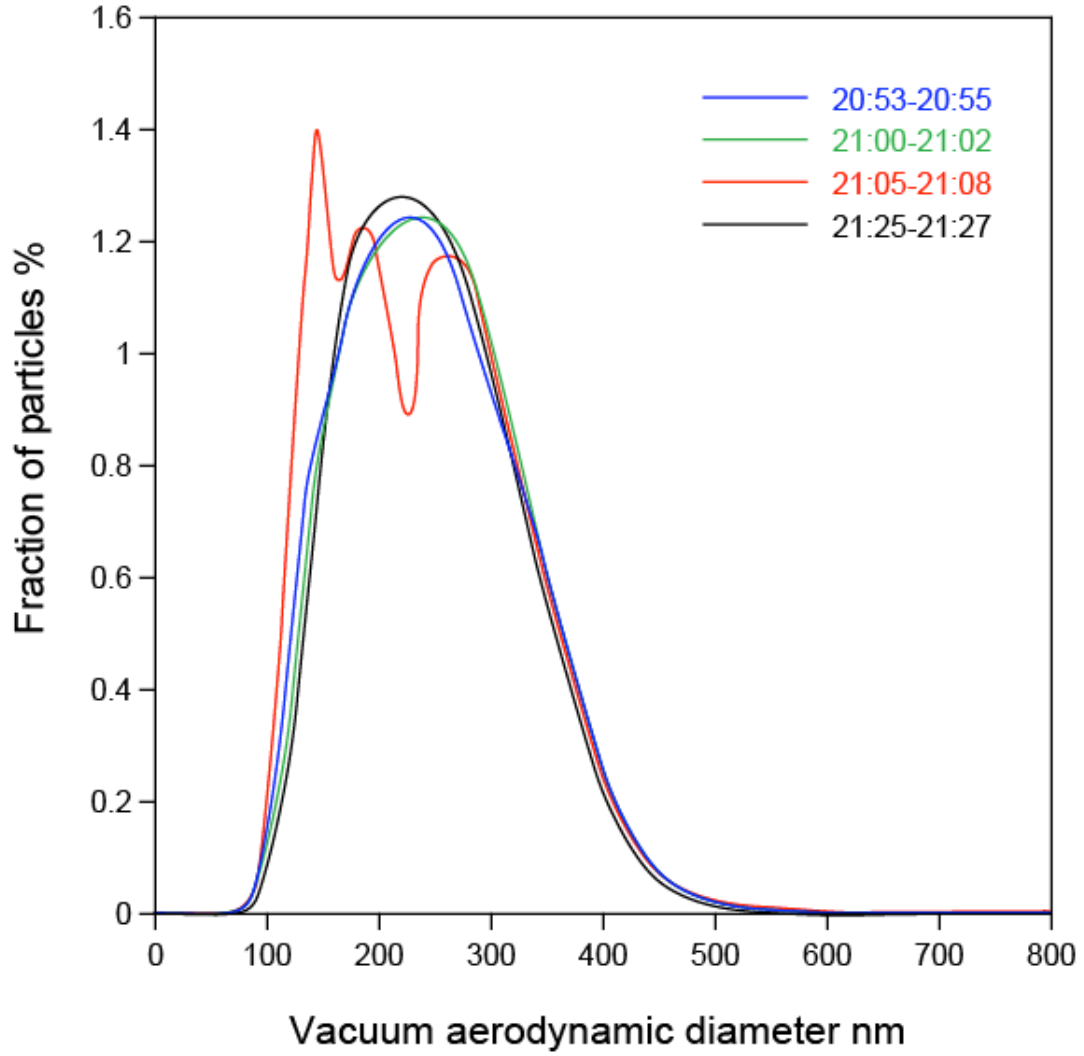
Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 25 Size Distributions

We measure the vacuum aerodynamic size distributions of particles larger than ~50 nm.

Here are a few examples from flight 25.

We also determine the size distributions of particles with specific compositions, which yields their effective density.



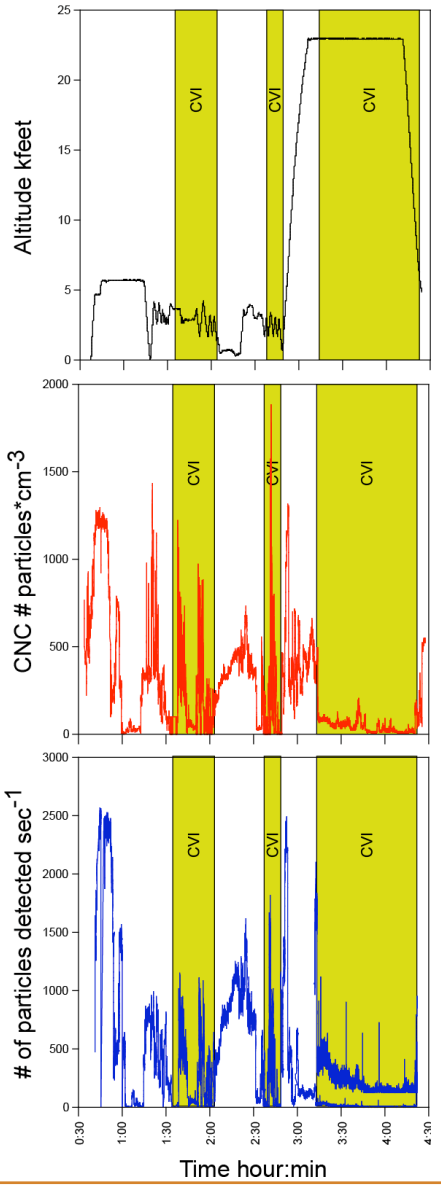
Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 26

The number of particles detected by SPLAT follows the CNC counter closely. Moreover, we understand where and why the two differ.

We sized over 7 million particles and measured the composition of ~140,000 particles on this day.

The data can be analyzed with temporal resolution of <1 minute.



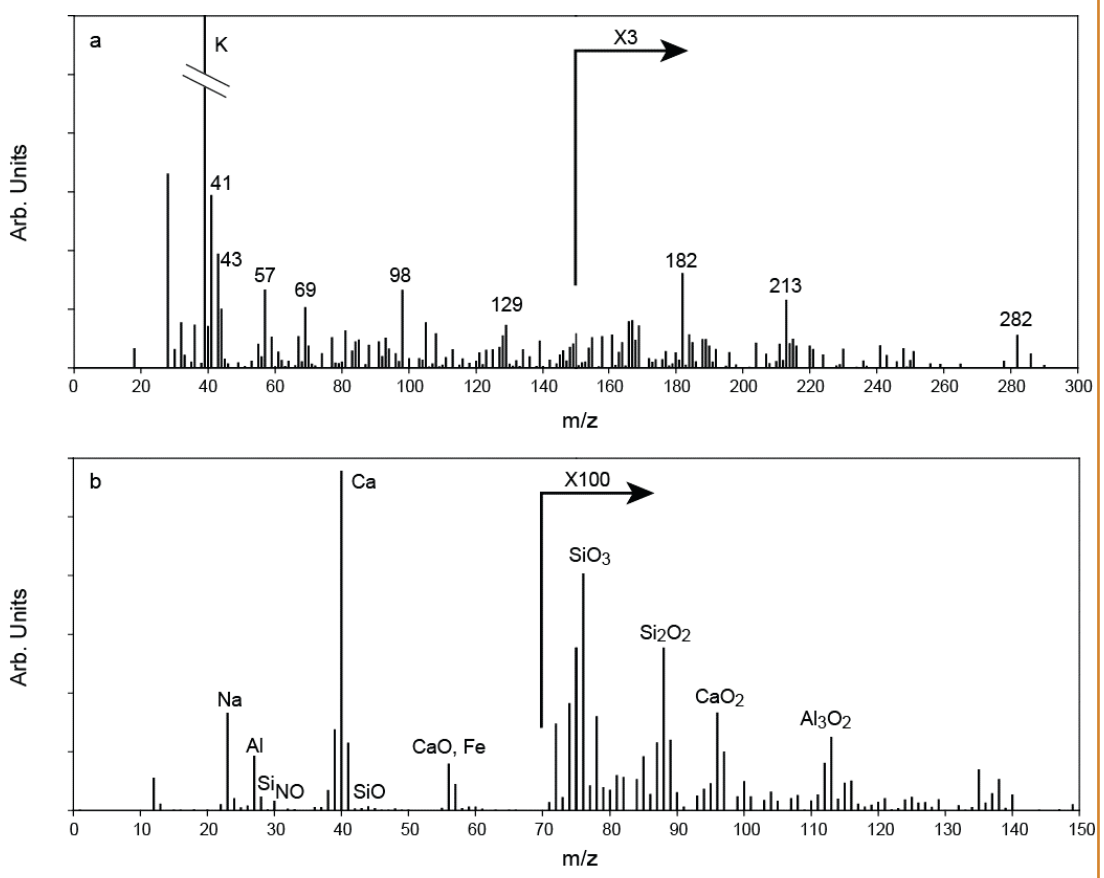
Pacific Northwest
NATIONAL LABORATORY

April 19 Particle Composition

Two individual particle mass spectra

A biomass burning particle

A Ca-dominated dust particle containing a small amount of sulfate that served as an ice cloud nucleus



Pacific Northwest
NATIONAL LABORATORY

April 19 Data Classification

Composition of 140,000 particles

We classify the mass spectral data and display the results in a circular dendogram that is explore able.

The data for flights 25 and 26 show that the vast majority of the particles fits into 5 major types:

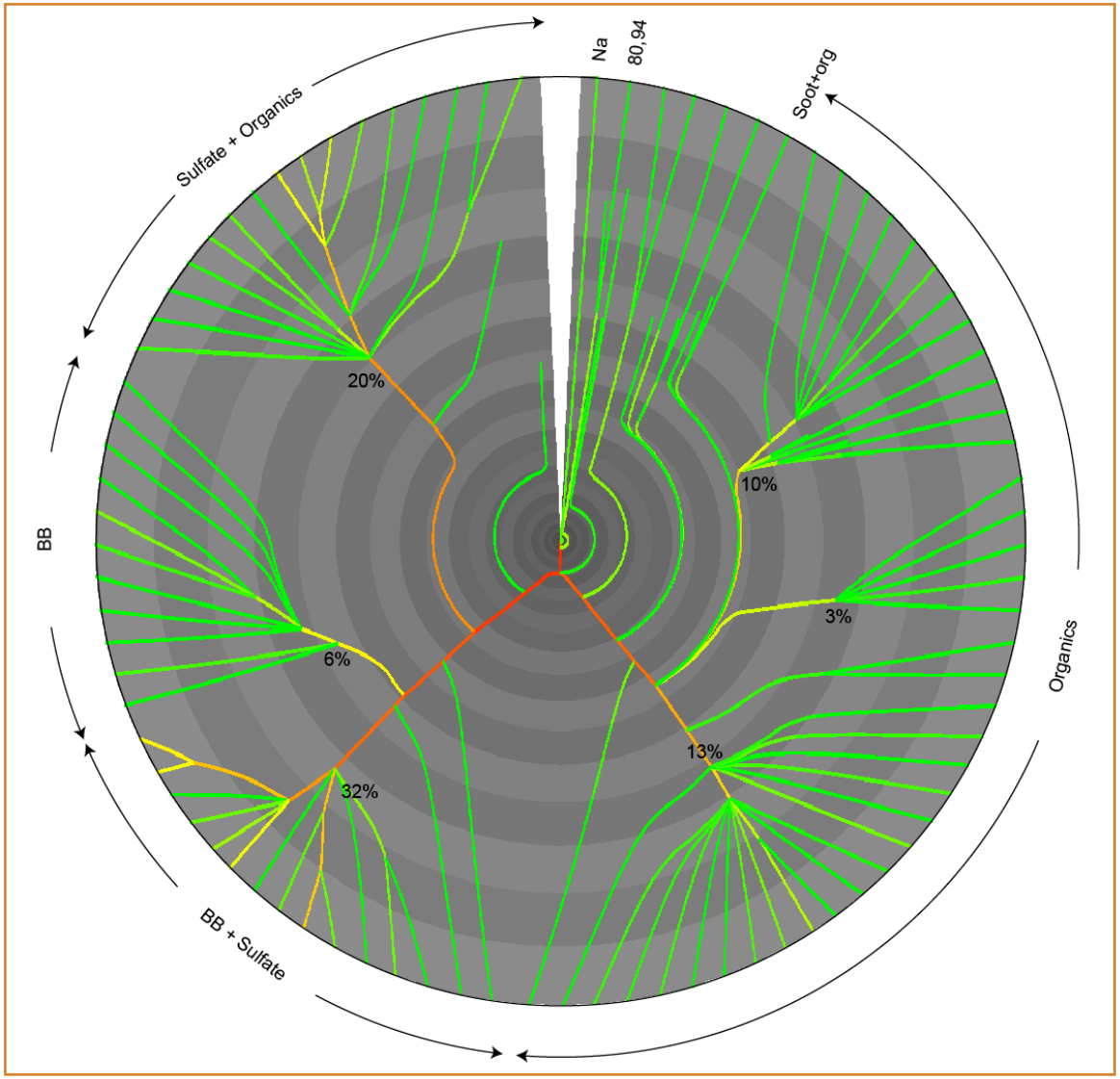
sulfate with some organics

BB

BB with sulfate

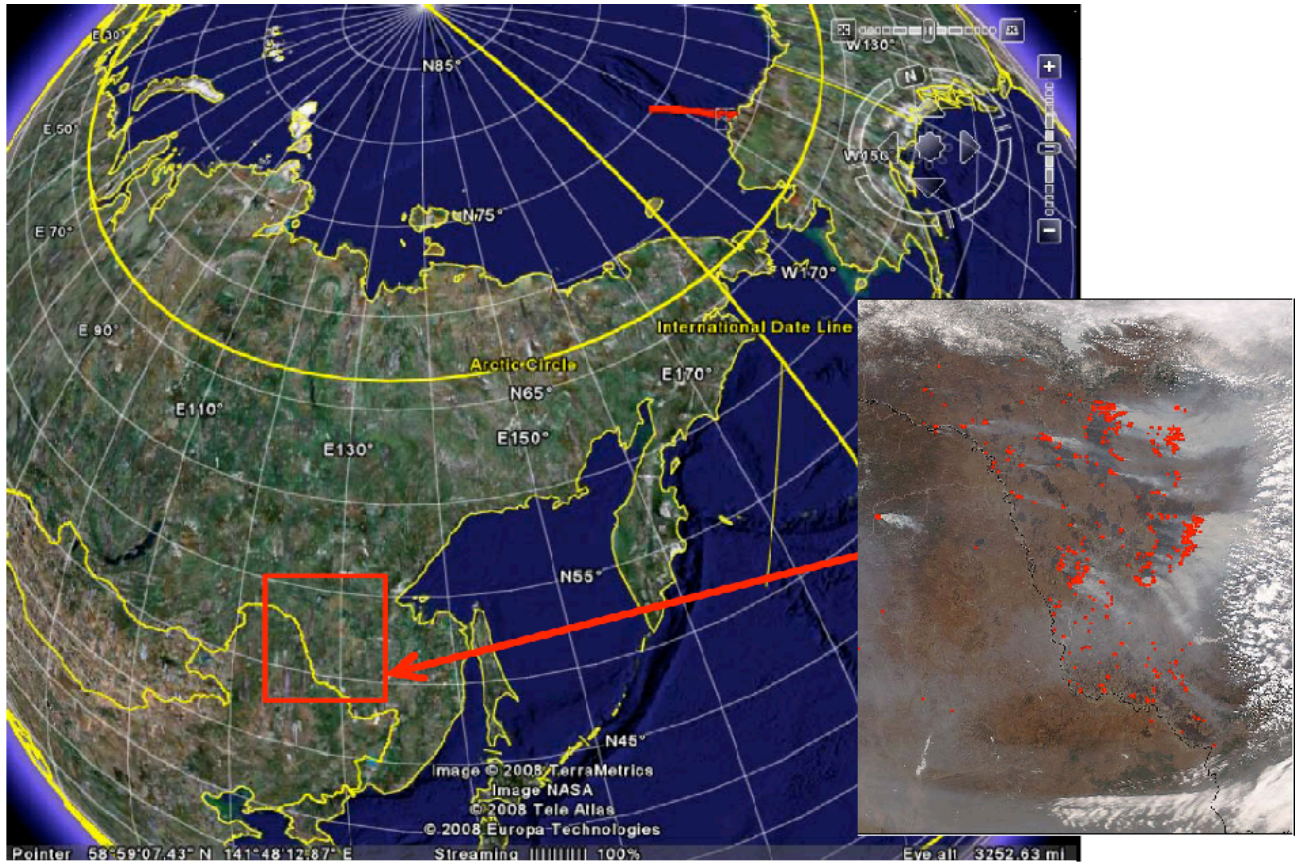
Organics

Others



Pacific Northwest
NATIONAL LABORATORY

Sources of Biomass Burning Particles

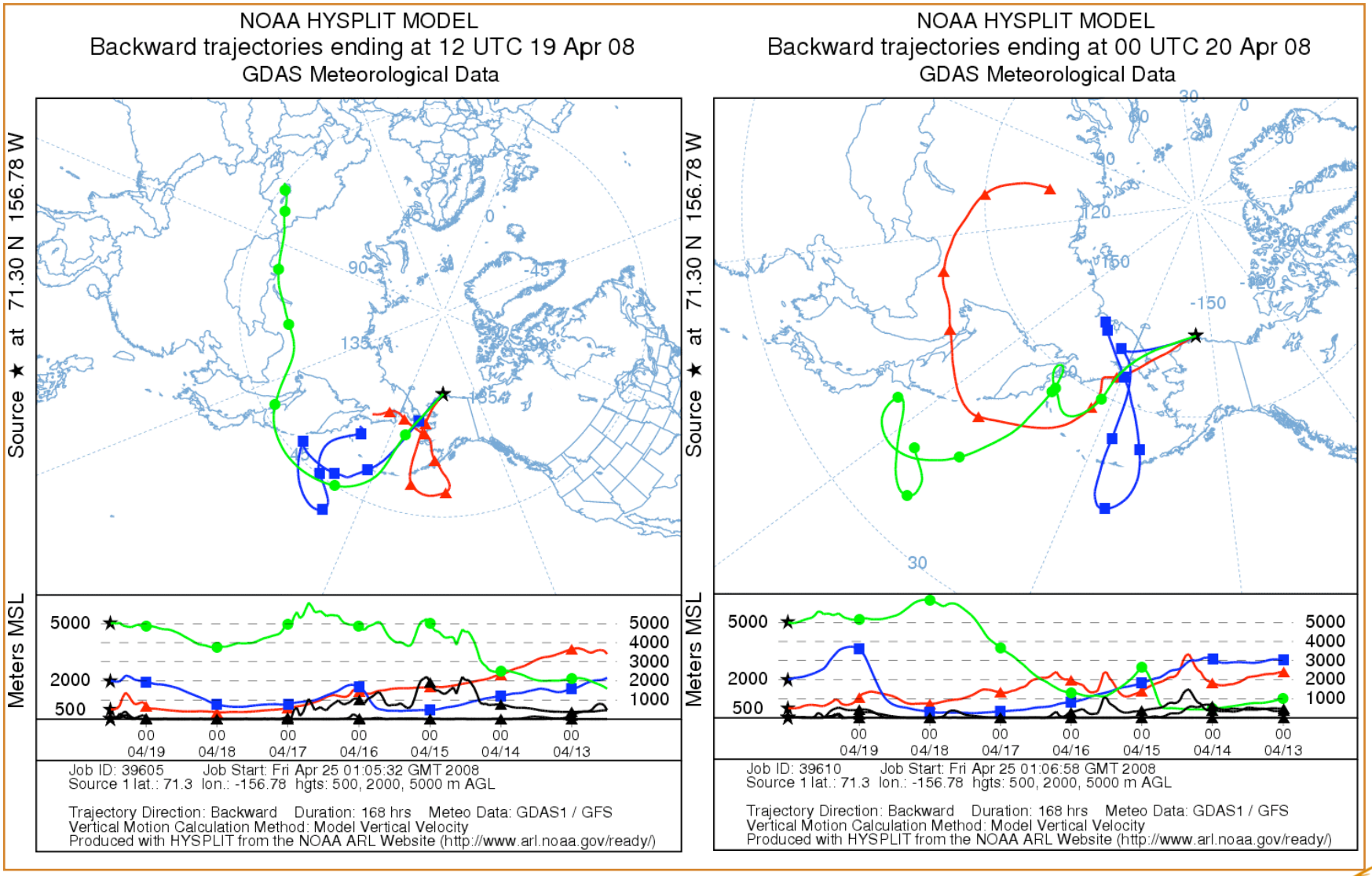


MODIS RapidFire 2008/106 - 04/15 04 :35 UTC Fires in eastern Siberia;
Smoke observed near Barrow April 19 ~ 22:00 UT

Richard Ferrare et al. NASA

Pacific Northwest
NATIONAL LABORATORY

Backward Trajectories



Pacific Northwest
NATIONAL LABORATORY

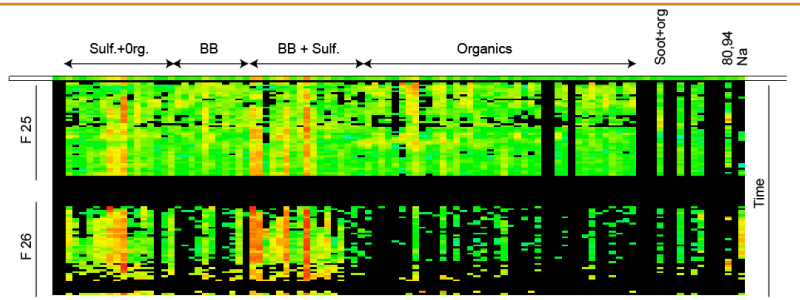
April 19 Time Evolution

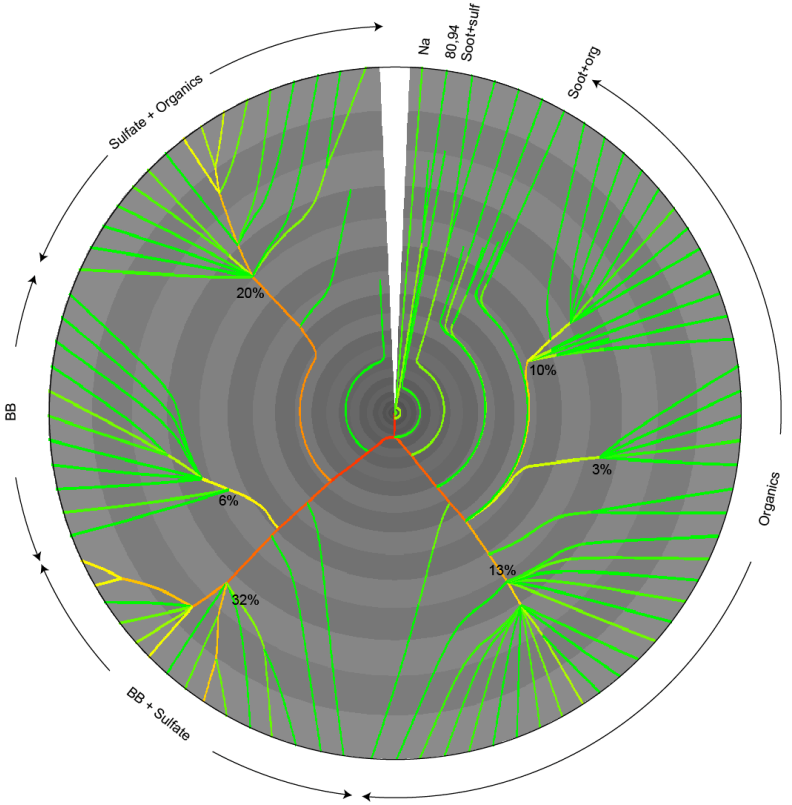
Composition and temporal evolution of 140,000 particles

We can also look at the changes in particle composition as a function of time.

Here we show an example of a movie with 5 minute resolution.

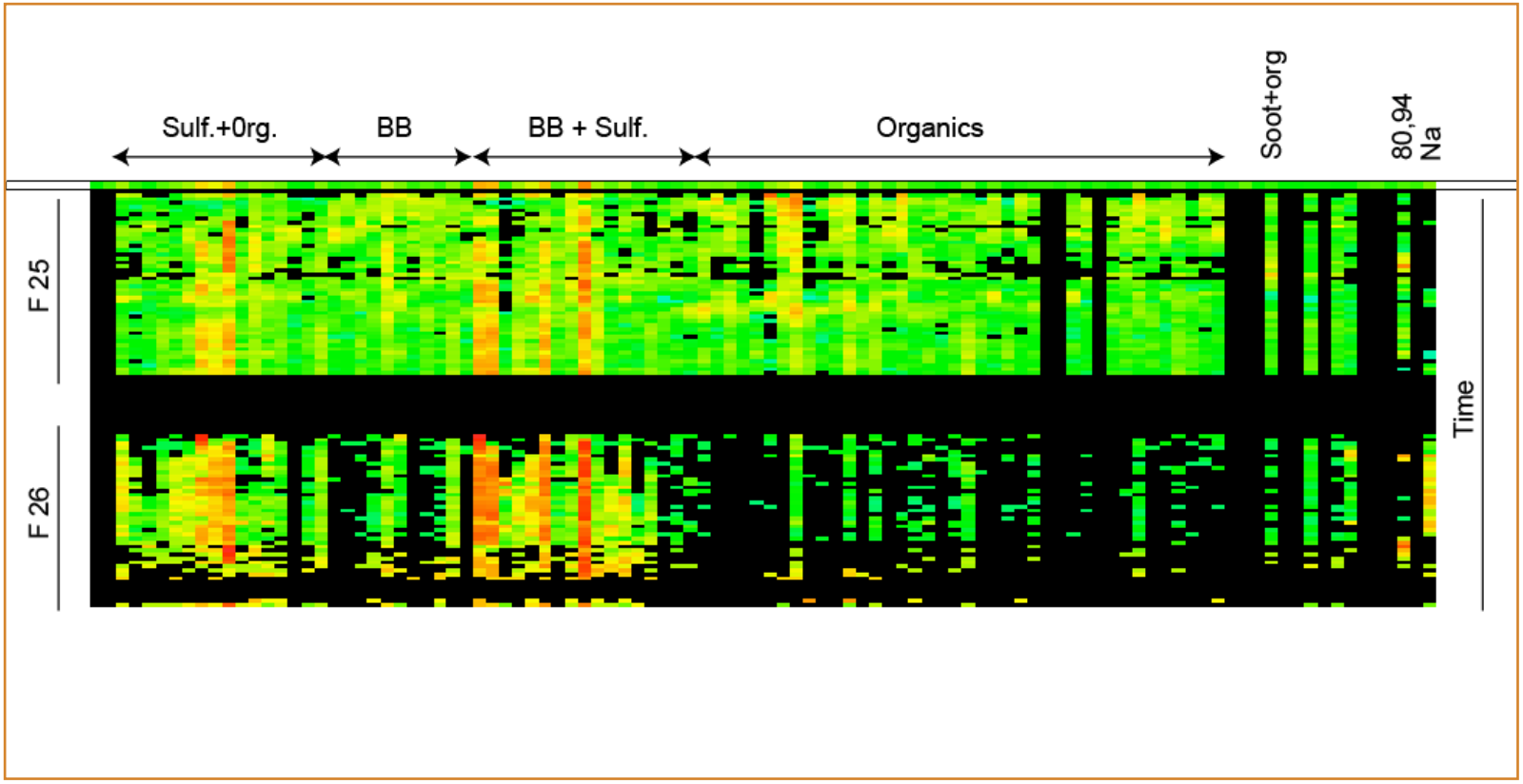
The two flight are clearly visible.





Pacific Northwest
NATIONAL LABORATORY

April 19 Time Evolution



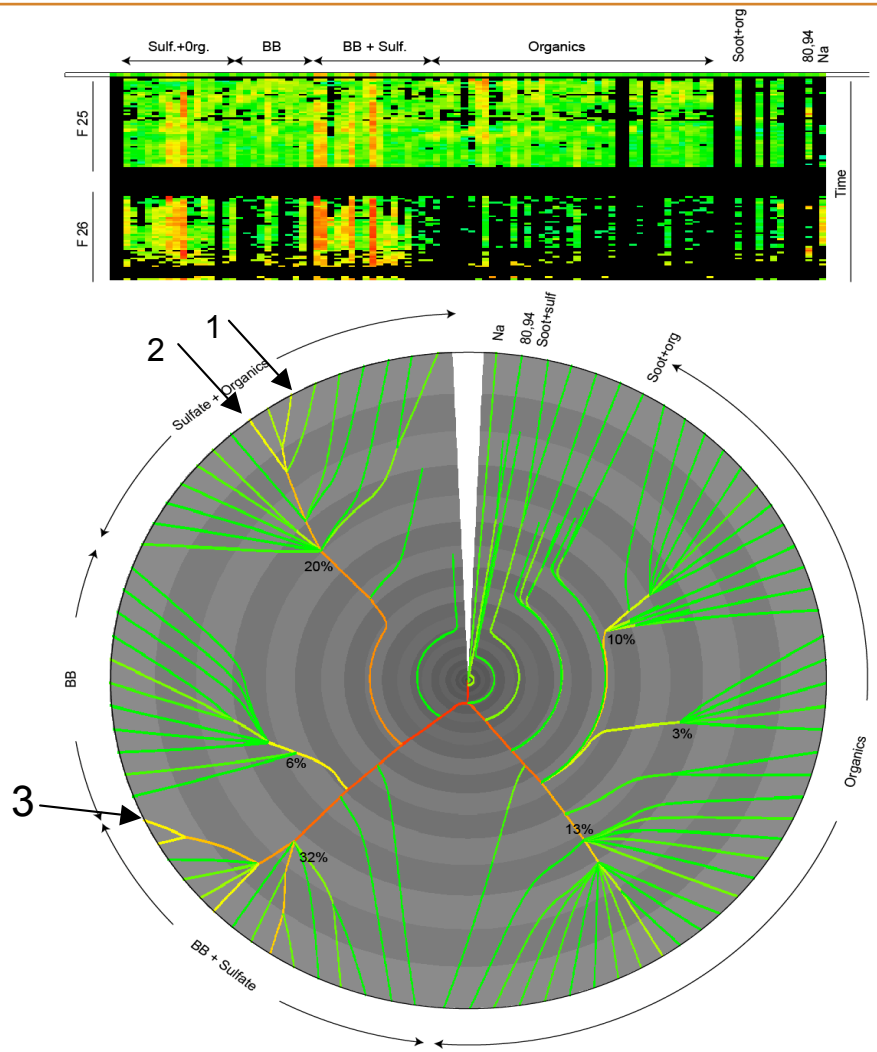
Temporal evolution of the composition of 140,000 particles

Here is a closer look at the time evolution. Again, the two flight are visible and one can easily see that the particle compositions are undergoing significant changes with time

Time Evolution of 3 Particle Classes

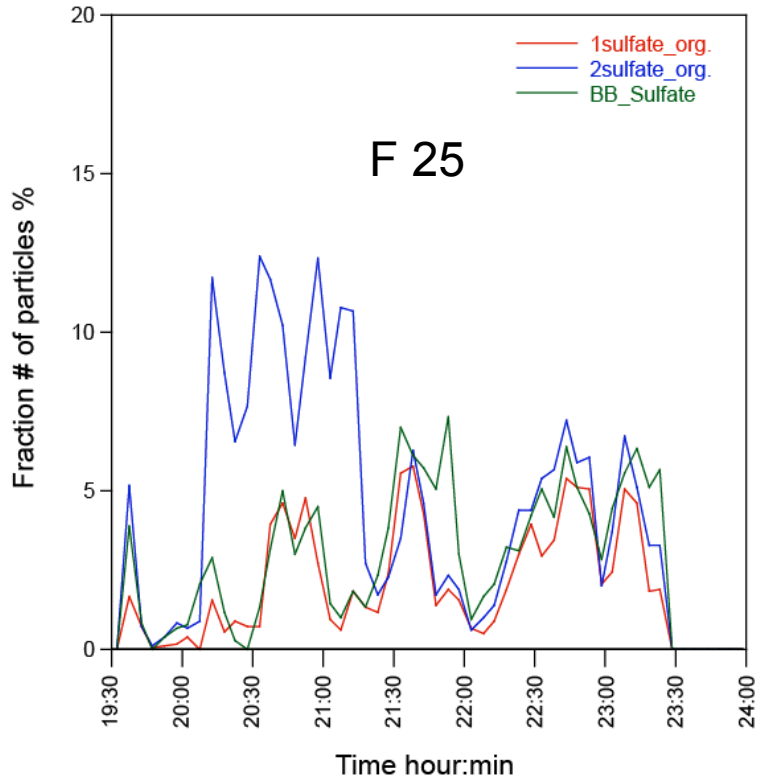
Composition and temporal evolution of 140,000 particles

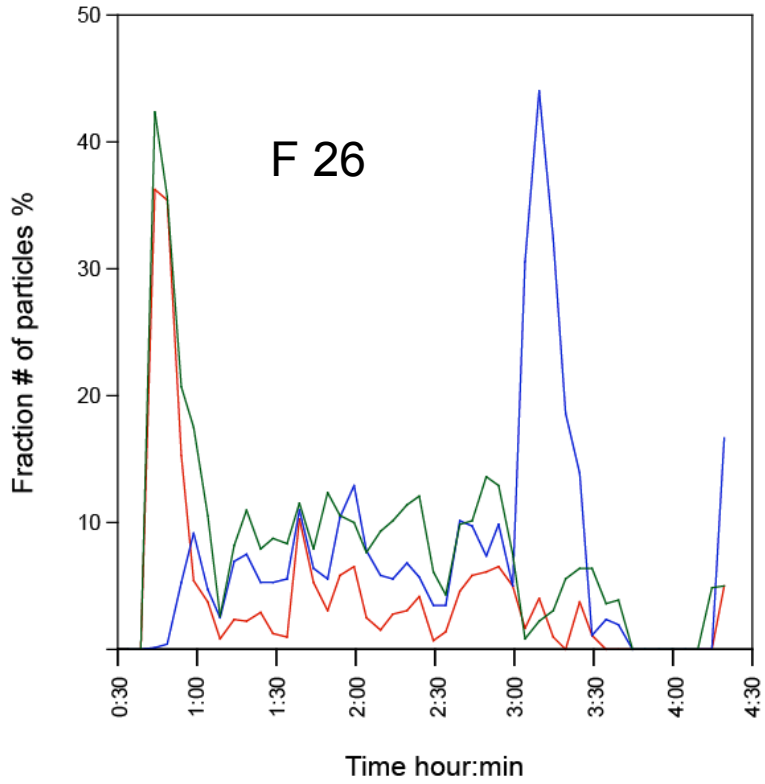
Example: Pick 3 classes and follow as a function of time



Pacific Northwest
NATIONAL LABORATORY

Time Evolution of 3 Particle Classes

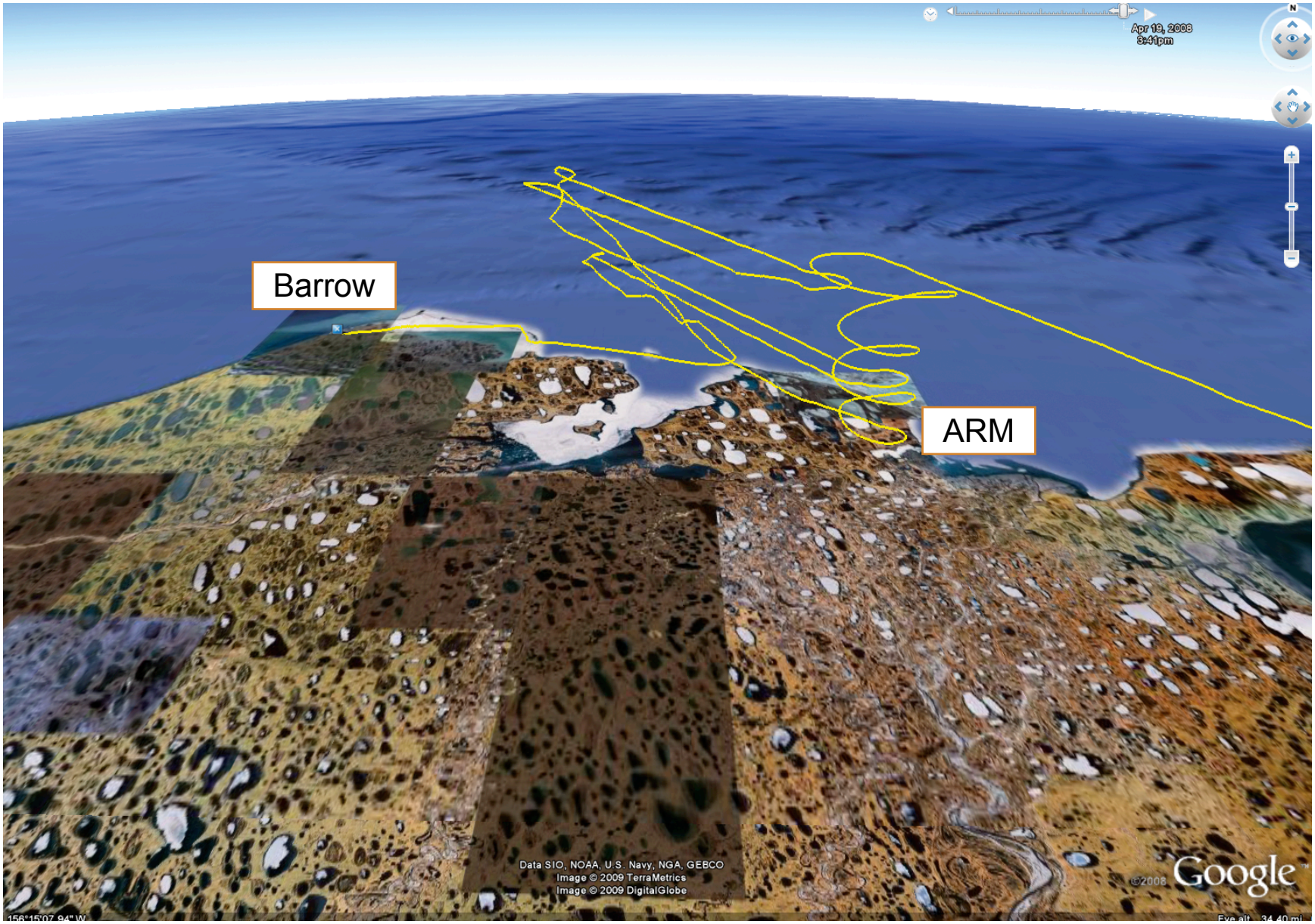




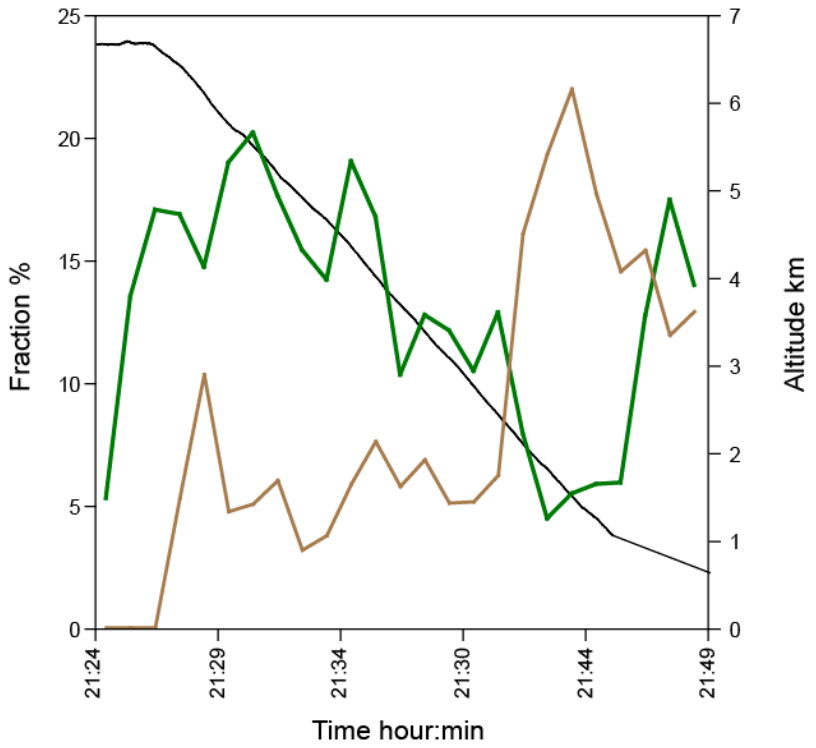
Classes marked as 1sulfate_org and BB sulfate are nicely correlated during both flights. In contrast class 2sulfate_org shows very different behavior during F 25 from 20:00 to 21:15, and 3:00 to 3:30 during F 26

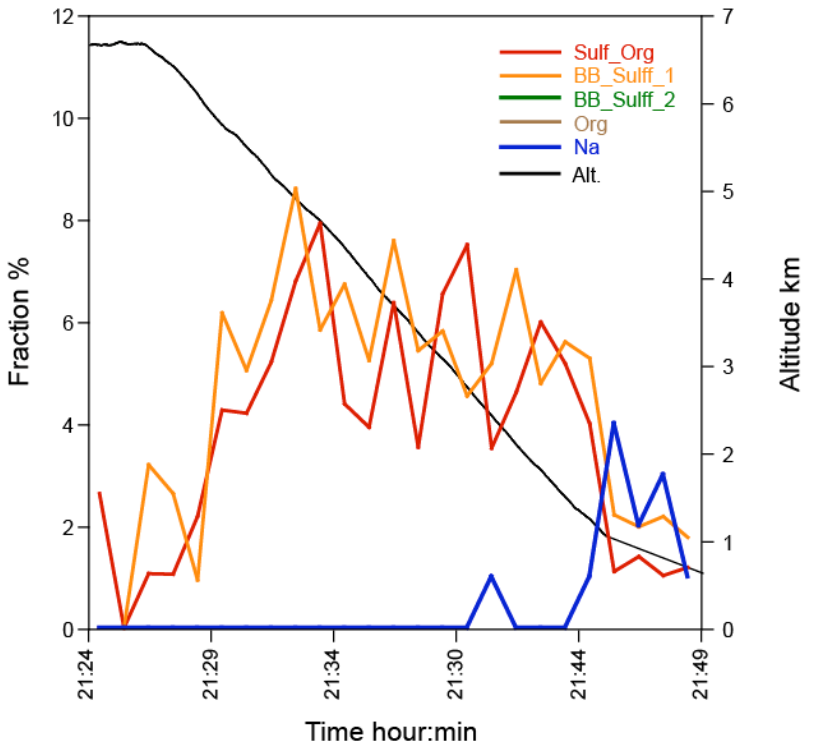
Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 25



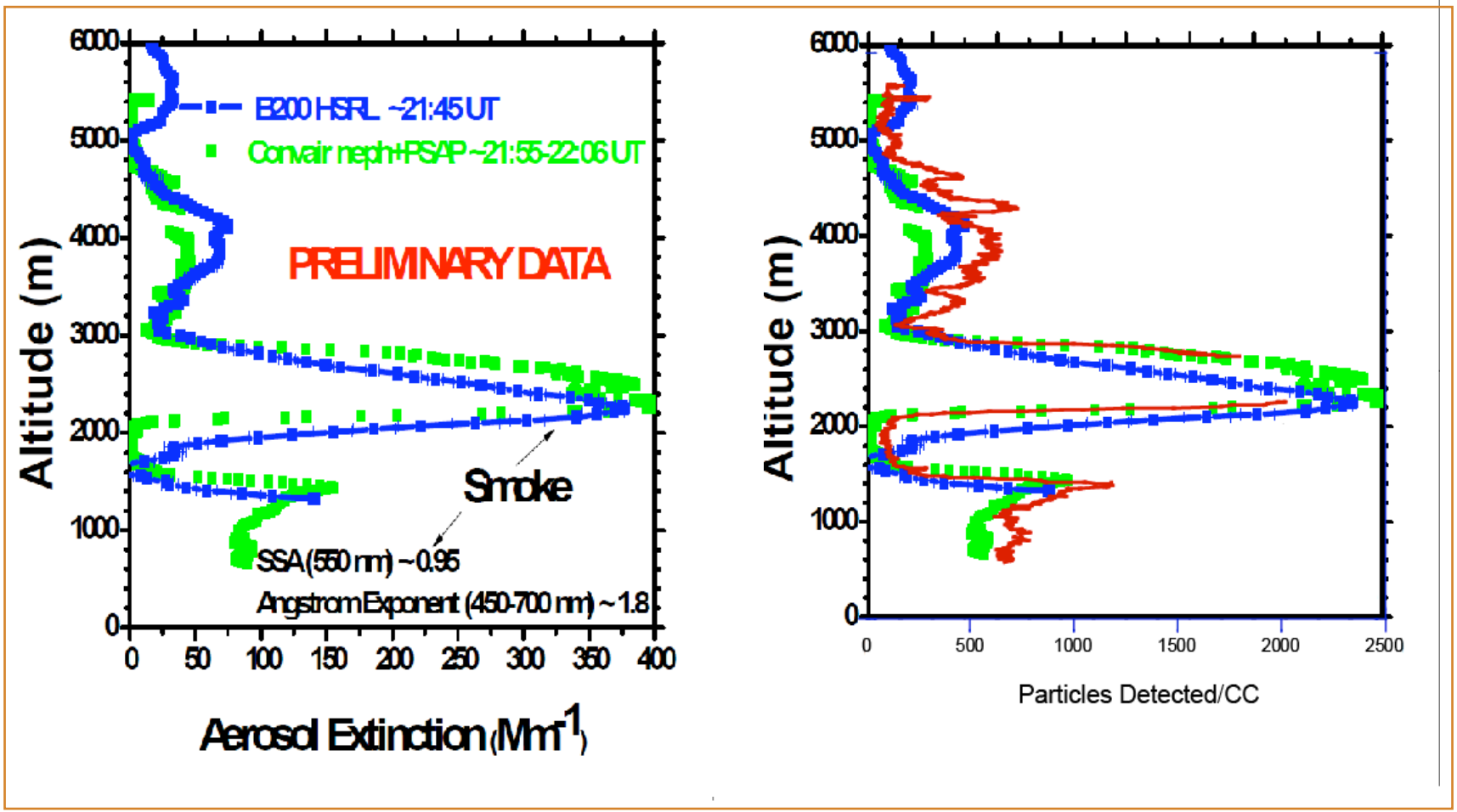
April 19th, Flight 25





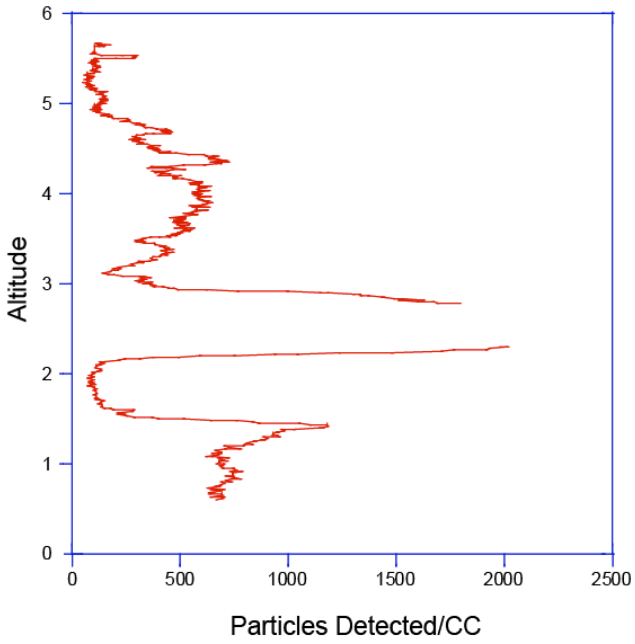
Pacific Northwest
NATIONAL LABORATORY

April 19th, Flight 25, 10 sec resolution

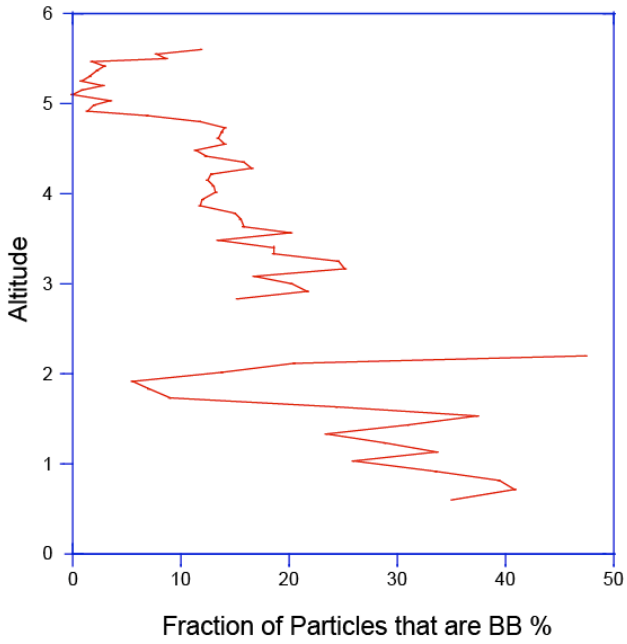


Pacific Northwest
NATIONAL LABORATORY

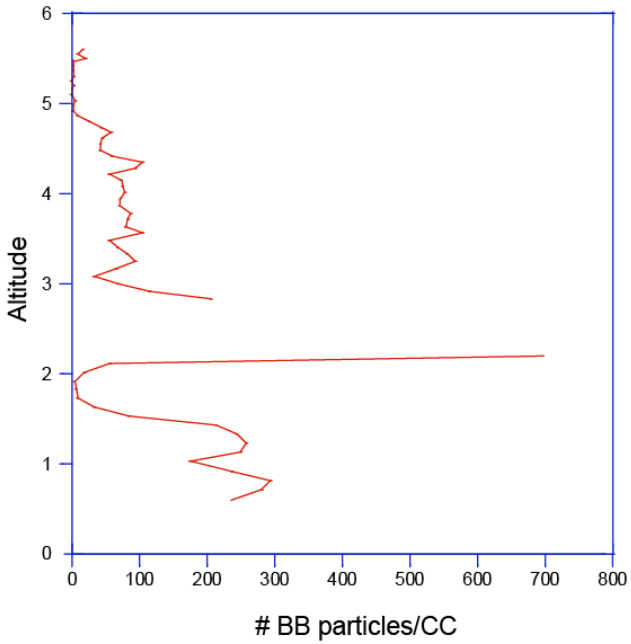
April 19th, Flight 25, 10 sec resolution



A plot of the number of particles detected by SPLAT as a function of altitude When the aircraft hit the heavily polluted layer SPLAT saturated and turned itself off. But the pattern is pretty clear.



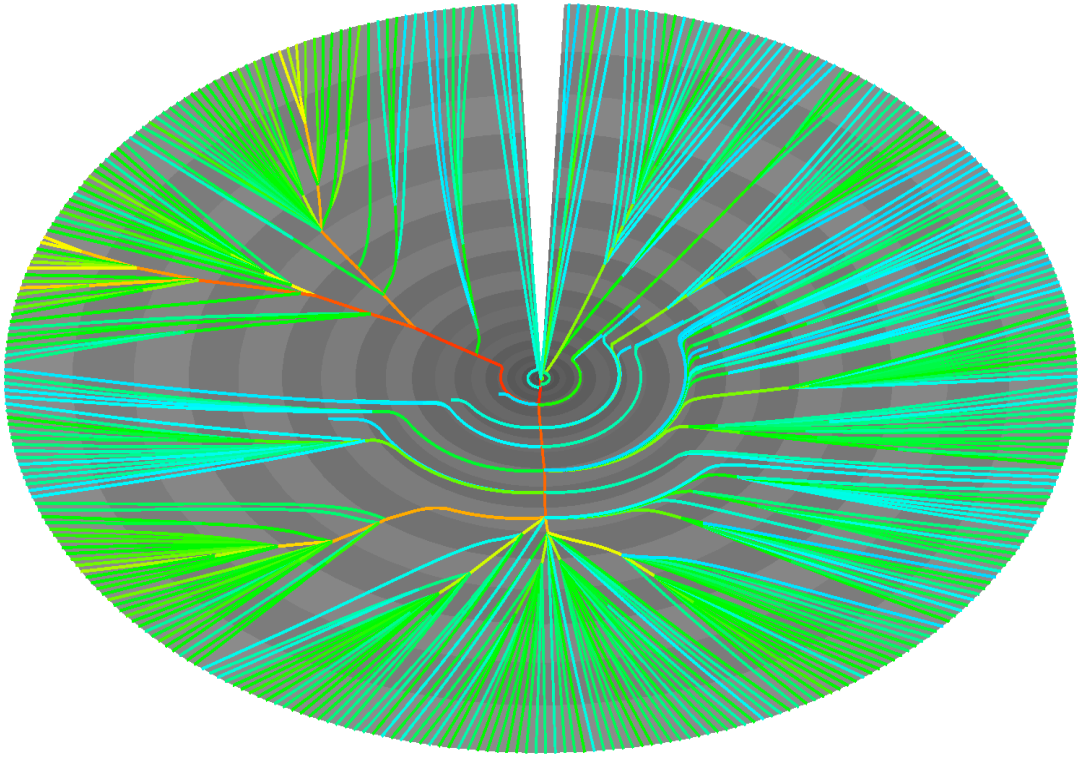
BB particles make up a significant fraction of the number of particles, especially at lower altitudes. We also see that particles at lower altitude are more spherical during this time period.



The number concentration of BB particles increases rapidly when the aircraft hits the polluted layer.

Pacific Northwest
NATIONAL LABORATORY

A Little More Detail



There are many types of particles

So far we looked only at classes with more than 300 particles. If we take a look at classes with more than 10 particles we find that there are many more types of particles. But the vast majority of them still belongs to the same large groups we mentioned before

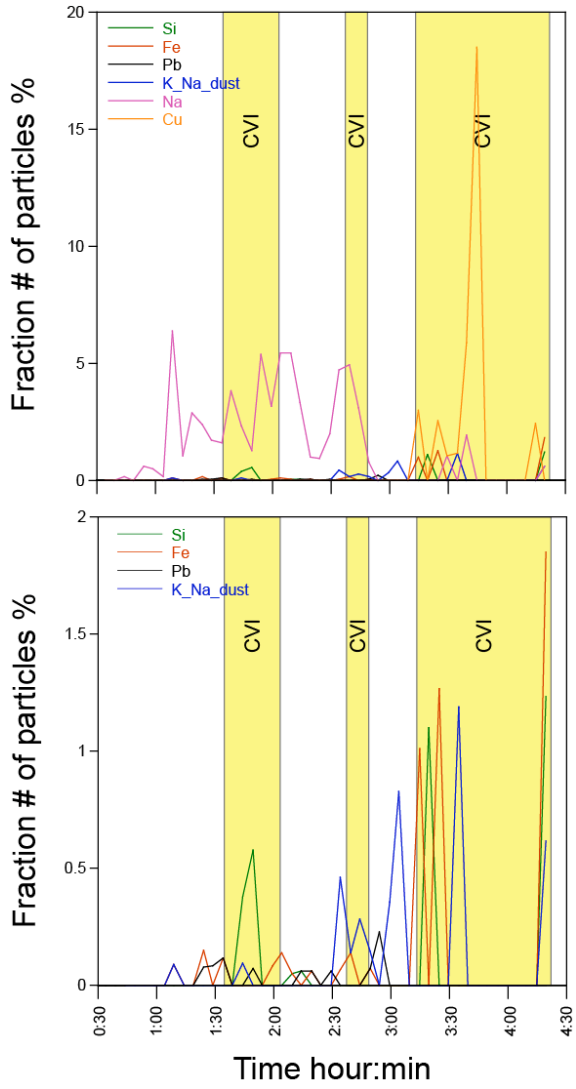
Time Evolution of “Special” Particle Classes

Temporal evolution dust, metallic and sea-salt

An event during which Cu particles made up ~20% of the detected particles occurred at 3:45 during F 26.

From 1:00 to 2:45 sea-salt particles represented ~2.5% of the total detected particles.

F 26



Pacific Northwest
NATIONAL LABORATORY

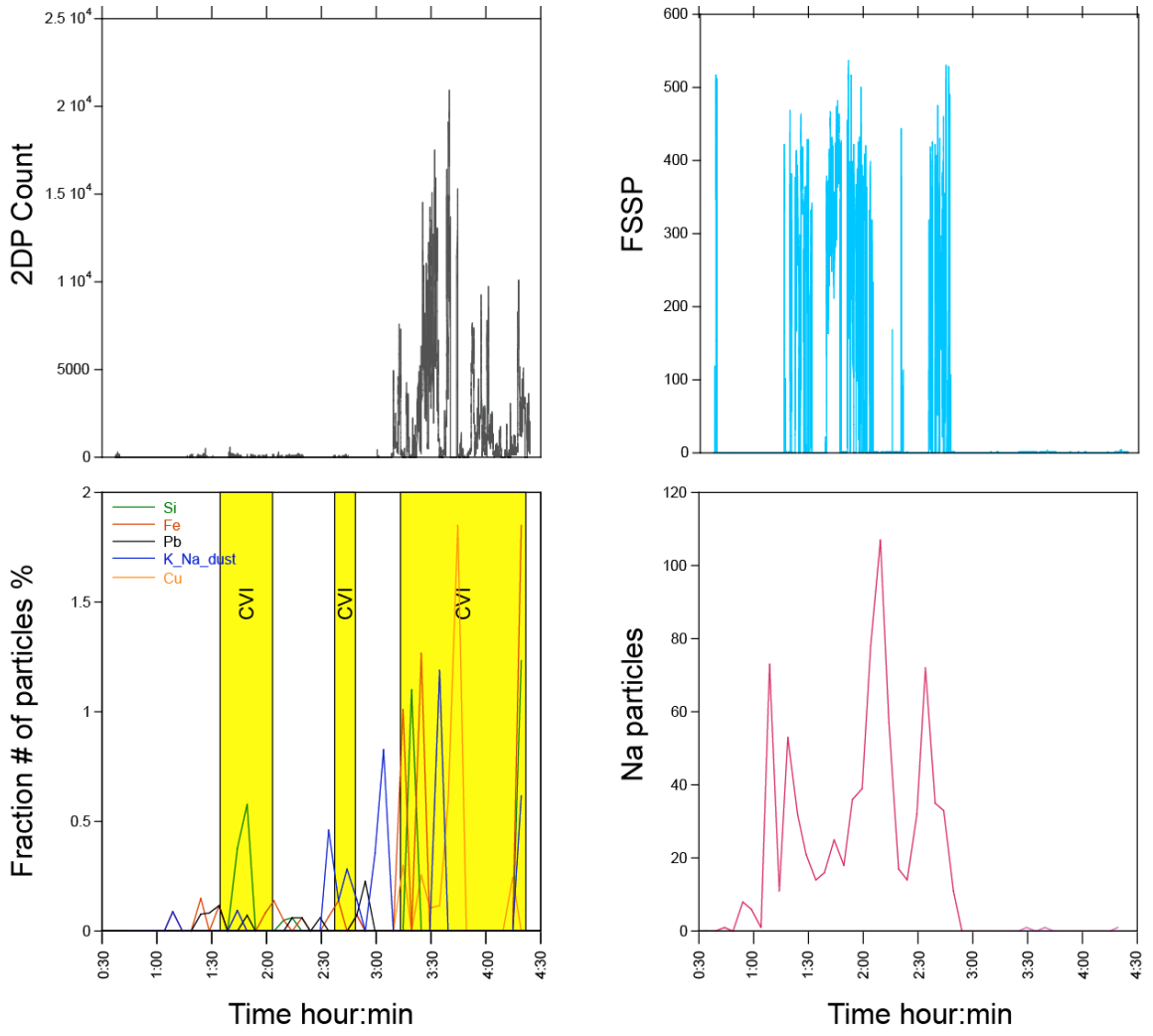
Time Evolution of “Special” Particle Classes

F 26

It looks like there is correlation between when SPLAT detects these metallic and dust particles and when the 2DP detects ice crystals.

This is not true for sea-salt particles.

Sea-salt particles seem to be very nicely correlated with the FSSP 100 counts



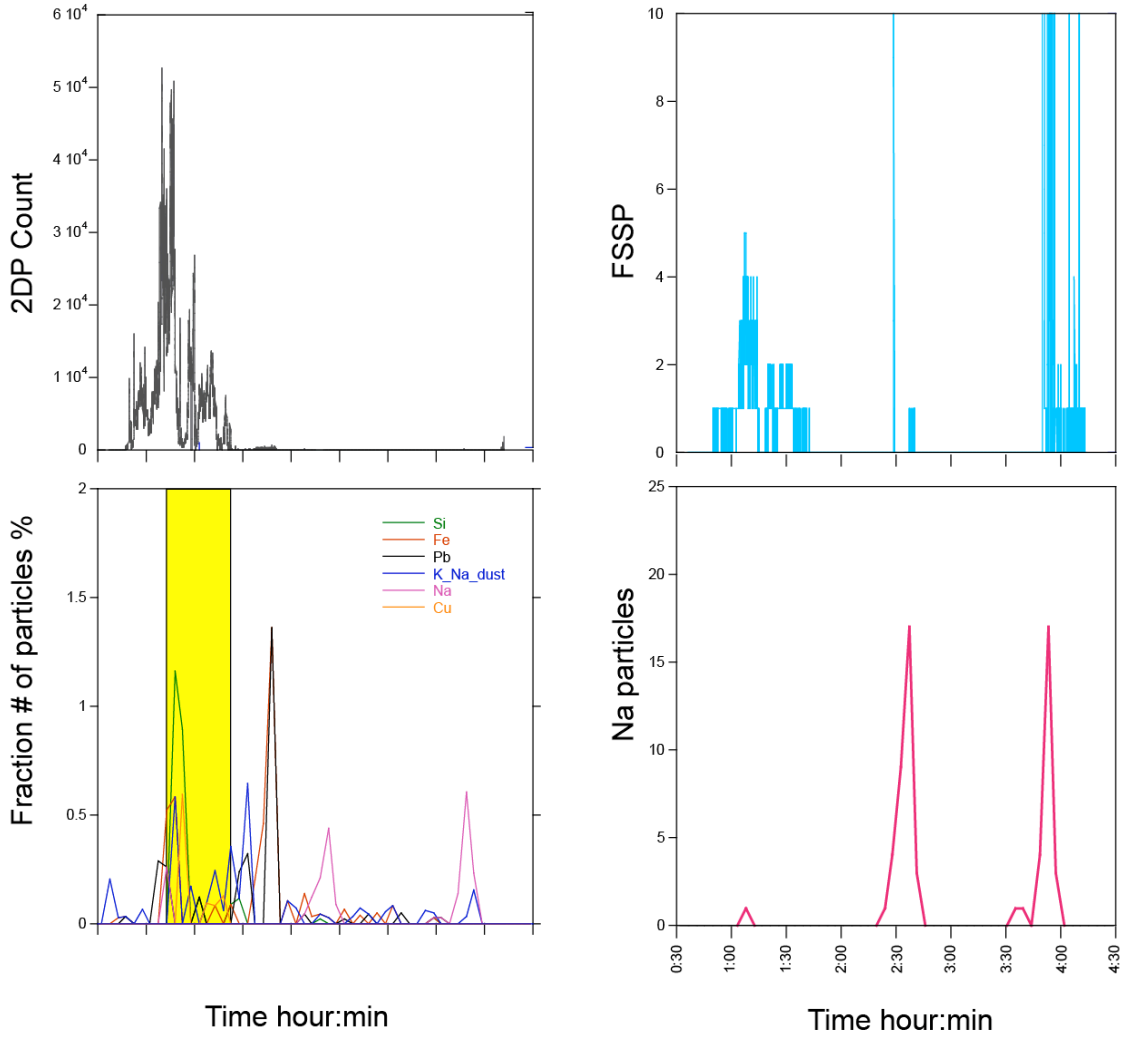
Pacific Northwest
NATIONAL LABORATORY

Time Evolution of “Special” Particle Classes

F 25

For this flight, the correlation is not that clear, but it might be there

Sea-salt particles seem to be very nicely correlated with the FSSP 100 counts



Pacific Northwest
NATIONAL LABORATORY

SPLAT II Data

- During ISDAC SPLAT II participated in all 27 flights (100+ hrs).
- 10s of millions particles were sized and over 3 million of them chemically characterized.
- SPLAT II characterized the composition and size of the overall aerosol population, and provided ***artifacts-free*** information on composition and size of particles that served as CCN and IN.
- SPLAT II measured a wide range of particle compositions, including sulfates mixed with organics, nitrates mixed with organic, processed and freshly emitted sea-salt, a few dust particles, and biomass burning particles. Many of these particle types appeared in aerosol layers that had horizontal and vertical filamentous structures. Biomass burning particles, many of which were transported from Asia, were rather prevalent over the North Slope of Alaska during the campaign.

Acknowledgments

Ashley Williamson, Charlette Geffen, Steve Ghan

John Hubbe

ISDAC team

Dan Imre	*Imre Consulting*
Peter Liu	*Environment Canada*
Anne Marie Macdonald	*Environment Canada*
Richard Leaitch	*Environment Canada*

Funding: BES and OBER (US DOE), EMSL

Pacific Northwest
NATIONAL LABORATORY